UPDATES ON DATA AND NEW DEVELOPMENTS AT CENTER FOR ENGINEERING STRONG MOTION DATA (CESMD) AND COSMOS

H. Haddadi¹, C. Stephens², A. Shakal¹, L. Gee², M. Huang¹ and J. Steidl³

ABSTRACT

The Center for Engineering Strong Motion Data (CESMD) is a joint effort of the U.S. Geological Survey (USGS) and the California Geological Survey (CGS) to provide access to strong-motion data from major earthquakes. The CESMD works closely with the USGS Advanced National Seismic System and with the Consortium of Organizations for Strong Motion Observation Systems (COSMOS) to engage with the strong-motion networks in the U.S. and other countries to receive, process and post records. As part of ongoing efforts to improve the capabilities of the CESMD, we have added the ability to search on information such as faulting type, Vs30, and Site Class as well as enhancing data conversion tools. New developments are underway to improve user access by merging two major databases, the Engineering Data Center and the Virtual Data Center, and to extend the automatic posting of strong-motion records from only California to all the Advanced National Seismic System (ANSS) regional networks.

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Introduction

The Center for Engineering Strong Motion Data (CESMD) collects and disseminates strong-motion records of ground and structural response that are of engineering importance. The Center, which is a cooperative effort between the U.S. Geological Survey and the California Geological Survey, was established in 2007 by expanding the scope of the Engineering Data Center of the California Integrated Seismic Network (CISN) to cover strong-motion records from all U.S. seismic networks as well as significant data from other countries. The operation and web portal of the CESMD are described in [1] and [2].

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This paper provides an update on the available strong-motion data, the Center’s operation, recently developed features in the search engine and the projects currently in progress at the Center. Also, the paper updates the activities of COSMOS and its cooperation with CESMD to promote usage of strong-motion data and to facilitate contributions from other strong-motion networks in data exchange.

**CESMD Operation**

The CESMD is operated from the CGS headquarters office in Sacramento and the USGS regional office in Menlo Park, California. Both offices currently have implemented data recovery and processing systems to receive, process and upload records to the CESMD server.

**Earthquake Information**

The CESMD receives earthquake information, such as location, origin time, magnitude, depth, focal mechanism and moment tensor from the USGS Product Distribution Layer (PDL) system. The PDL Watcher system at the CESMD receives the earthquake information, uploads it to the database and initiates the process for generating a corresponding Internet Quick Report (IQR). The basic earthquake parameters, such as location, magnitude and origin time, are generally received within a few minutes after an event occurs, and the database is updated as new event information becomes available. As strong-motion records are received, the IQR station table is populated with the metadata. The IQR also includes an interactive map displaying the location of the earthquake and the reporting stations and a link to the ShakeMap.

**Strong-Motion Data Processing**

The Center receives raw (unprocessed) and/or processed (noise removed) data from strong-motion networks, depending on the policy of the network. Some networks allow CESMD to process, or re-process data if needed, while others would prefer to provide unprocessed data only. In some cases, the network provides links to their data archives. CESMD accommodates the preferences of the seismic networks.

**Strong-Motion Data of CISN**

Raw strong-motion data from the CISN networks are automatically transmitted to the California Strong Motion Instrumentation Program (CSMIP) office of CGS in Sacramento where they are processed by the CSMIP Strong-motion Automated Recovery and Analysis (SARA) System [3] to remove noise and generate products that include time series for acceleration, velocity, and displacement as well as spectral acceleration, and plots of the data. If the records have not already been associated with an earthquake by the authoritative network, then that association is also made. The strong-motion data (raw and processed) and the plots are loaded into the CESMD within a few minutes after an earthquake’s occurrence.

**Strong-Motion Data of other ANSS Seismic Regions**

The USGS National Strong Motion Project (NSMP) in Menlo Park, CA acquires strong-motion
data from their network and other ANSS (Advanced National Seismic System) regional networks and processes the records. The strong-motion data and products, including plots of ground motion time histories and spectra, are then uploaded to the CESMD. As described later, the USGS NSMP has developed software to automatically acquire and process data from all of the ANSS seismic regions, and is engaged with CGS to develop software and protocols for automatically uploading these data and products to the CESMD.

**Strong-Motion Data of Other Countries**

The Center also serves strong-motion data of significant earthquakes that occur outside of the U.S. contributed by other networks. In general, the events with magnitude 5.5 and larger and depth of 100 km or shallower are included, but other records may be included if they are significant due to particular features of the records such as unusual ground motion or frequency content. The data from other countries may include only raw (unprocessed), as those from Japan, or both raw and processed, as those from New Zealand. For Japan, New Zealand and Italy earthquakes, the strong-motion records are available for upload to CESMD sooner than for other seismic regions. Usually CESMD uploads such records within one day to one week, depending on the availability of records. For the records of other countries, CESMD staff may need to contact the network authorities and arrange to receive data. Availability of such data depends on the networks policies to disseminate data publicly. Figure 1 shows the CESMD page for the most recent and latest significant earthquakes.
Figure 2 shows the CESMD EDC Data Report page for the M7.8 earthquake of 13 November 2016 in Amberley, New Zealand.

Available Strong-Motion Data at CESMD

The parameters used to select earthquakes to include in the Center’s database are the event magnitude and peak ground acceleration and the seismic region in which it occurs. An earthquake in the U.S. with magnitude 4.5 and larger that has a record with peak ground acceleration exceeding 5%g is included in the data center. However, the threshold for including earthquake is lowered to magnitude 4.0 in Center and East US, and to magnitude 3.5 in California. International earthquakes with magnitude 5.5 and larger that have records with peak ground accelerations of minimum 10%g are included in the CESMD (Figure 3).
Today, the CESMD EDC holdings consist of over 14,500 multiple trace records from about 740 earthquakes, from magnitude 3.5 to 9.0. Over 5,100 stations are in the database, including 3,400 ground response sites, 36 geotechnical arrays, and 470 structures (buildings, dams, bridges, and other lifelines). Also the CESMD VDC holdings consist of about 66,000 traces from over 1,260 earthquakes recorded at about 5,600 stations. Recent notable events at the CESMD include the Nov 13, 2016, M7.8 Amberley, New Zealand; Oct 30, 2016, M6.6 Northern Norcia, Italy; April 15, 2016 M7.0 Kumamoto-shi, Japan; and the April 1, 2014, M8.2 Iquique, Chile.

In order to assure the records are of engineering interest, CESMD applies a separate Peak Ground Acceleration (PGA) threshold of 0.5% g for records displayed on the event pages. Records that do not meet this threshold are not included in the IQR. However, there is a growing interest from the user community in records with lower ground motion amplitudes for special projects such as the PEER NGA Ground Motion Prediction Equation project. For such studies, records for earthquakes with magnitude 3.0 to 3.5, and PGA of 0.1% g and larger, and for larger magnitude earthquakes with PGA from 0.1% g to 0.5% g, have been loaded to the CESMD ftp site, where they are available in event directories. At this time, these records are not searchable, although the CESMD is planning to make these data searchable in the future. Users can access the ftp site through the link at the bottom of the IQR pages or in the Engineering Data Center (EDC) search page.

The CESMD has also posted ambient records of some selected structures at the ftp site. Access to the ambient records is through a link in the EDC search page.
The CESMD has two web portals, one for the US Structural and Ground Response Data at the Engineering Data Center (EDC), and the other for Worldwide Ground Response Data at the Virtual Data Center (VDC).

New Parameters at CESMD Search and Station Information Pages

Both the EDC and VDC offer the capability to search for strong-motion records that meet specific criteria. The CESMD has recently expanded the search capabilities of the EDC to include the Site Class of a station (where available) and the earthquake faulting type. Figure 4 shows the updated Search Page of CESMD EDC with the new search parameters.

Vs30 Parameter

The parameter Vs30 is now available for a number of strong-motion stations in the CESMD database, and efforts are in progress to determine Vs30 at other stations. The Vs30 value in CESMD is specified either as measured or inferred, and a reference to the data source has been added to the station page (Figure 5). When measured Vs30 is not available, inferred Vs30 values, taken from sources such as [4], [5] and [6] in which surface geology, slope and topography are used to estimate Vs30, are listed. The site information, including the method used to measure or
infer Vs30, and source for determining Site Class [7], are displayed in Site Information Sources pages.

**Site Class**

For a large number of stations in California, CESMD shows Site Class in the station page. Some Site Classes are determined in geotechnical studies reports, but most of them are determined by using Vs30 according to the definition of Site Class in Table 20.3-1 in Chapter 20 of ASCE 7-10 [7]. To consider uncertainty of Vs30 in determining site class, for the cases where the Vs30 value is near the lower boundary of a Site Class (within 5%), the Site Class is noted as A/B, B/C, C/D or D/E.

The site information, including the method used to measure or infer Vs30, and source for determining Site Class, are displayed in Site Information Sources pages. Figure 6 displays the corresponding Site Information Sources page for the station shown in Figure 5.

**Faulting Type**

The CESMD automatically receives moment tensor and focal mechanism information for an earthquake from the USGS PDL within a few minutes after origin time. The CESMD utilizes moment tensor information to determine faulting type, but in the case that a moment tensor solution is not available, focal mechanism information is used to determine faulting type.
CESMD and COSMOS Cooperation

The Consortium of Organizations for Strong Motion Observation Systems (COSMOS) promotes collaboration among programs and institutions to improve strong-motion measurements, solve mutual problems with instrumentation and data, and assist in strong-motion data dissemination.

CESMD regularly participates in the COSMOS Strong-Motion Forum as a venue for communicating with strong-motion networks of other countries about exchange matters and work on mutual issues.

COSMOS Converter Tool

To facilitate strong-motion data usage, COSMOS has developed an application to read strong-motion data in major seismic data formats, view time histories and convert data between different formats, including MATLAB, XML, and tagged and single column ASCII. The COSMOS Converter Tool is developed in Java and runs on any computer platform. At this time, the COSMOS Converter Tool can view and convert data in the USGS SMC, CGS, COSMOS V1.2 and international formats including GNS in New Zealand, NIED in Japan, and RENADIC of Chile. Additional development to support other formats is underway. The COSMOS Converter Tool application is available for download at: http://www.cosmos-eq.org/VDC/index.html.

Projects in Progress

The CGS and USGS staff who are involved in the CESMD are currently working on several projects to improve the functionality of the Center’s web portal. Two of the projects are described below.

Figure 6. This figure displays Site Information Sources page of CESMD for the station shown in Fig. 5.

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Automation of US-wide IQR Page Generation

In order to facilitate access to the strong-motion data from the ANSS, the USGS has developed a system to automatically retrieve and process records of strong-motion data from ANSS regional seismic networks. The system uses an implementation of the AQMS (ANSS Quake Monitoring System) software to retrieve the waveforms and generate COSMOS V0 files for events of interest. The V0 files are passed to the PRISM (Processing and Review Interface for Strong Motion Data) software, which is designed to process raw strong-motion acceleration time series to produce compatible acceleration, velocity and displacement time series, acceleration, velocity and displacement response spectra, Fourier amplitude spectra, and standard earthquake-engineering intensity measures [8].

The goal is to automate the process of retrieving and processing ANSS strong-motion data for posting at CESDM. As part of this effort, CGS is expanding the ability to generate IQR pages to cover US-wide events at the CESMD.

CESMD Merged Database

As described earlier, the Center currently supports data portals to two separate databases of strong motion records. This historical legacy means that users need to check both databases in order to obtain all relevant records and requires the CESMD to support two database structures. To address these issues and help streamline operations, CESMD has undertaken a project to create a new, common database that merges the holdings of the EDC and VDC. As a first step, we plan to continue supporting data access via the EDC and VDC web portals, with a long-term goal to merge the web portals and search engines and provide enhanced capabilities.

Summary

The Center for Engineering Strong Motion Data (CESMD) provides strong-motion data of ground and structural responses to engineering interests through its Engineering Data Center (EDC) and Virtual Data Center (VDC). The CESMD operates from the CGS headquarters office in Sacramento and the USGS regional office in Menlo Park, California. Both offices receive strong-motion data from the contributing networks, process and serve records and other products. The CESMD EDC holdings consist of over 14,500 records of multiple traces from about 740 earthquakes, from magnitude 3.5 to 9.0. The VDC holdings consist of about 66,000 traces from over 1,260 earthquakes. Over 5,100 stations are in the database of EDC, including 3,400 ground response sites, 36 geotechnical arrays, and 470 structures. Over 5,600 stations are in the database of VDC. Recent notable events at the CESMD include the Nov 13, 2016, M7.8 Amberly, New Zealand; Oct 30, 2016, M6.6 Northern Norcia, Italy; April 15, 2016 M7.0 Kumamoto-shi, Japan; and the April 1, 2014, M8.2 Iquique, Chile.

Several recent changes have been made to facilitate data access. New parameters of station Vs30 and Site Class recently have been added to the search parameters of CESMD EDC. Also, strong-motion data are now searchable by earthquake faulting type.

The automated process for retrieving, processing and uploading strong-motion data to CESMD for
California earthquakes is being expanded nationwide. Upon completion, strong-motion data of all ANSS seismic regions that are acquired automatically by the USGS NSMP in Menlo Park will be posted at the CESMD within a few minutes after an earthquake occurs. COSMOS facilitates cooperation of seismic networks with CESMD through its Strong-Motion Forum. COSMOS has provided guidelines and standards on a variety of topics related to strong-motion instrumentation, site characterization, data processing, etc. Also it has developed an application named COSMOS Converter Tool to read strong-motion data in major seismic data formats, view time histories and convert data in different formats, including MATLAB, XML, tagged and single column ASCII.

The CESMD staff routinely respond to data users questions on strong-motion data and station information and provide assistance on utilization of strong-motion data.

References


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7. American Society of Civil Engineers. Minimum Design Loads for Buildings and Other Structures, ASCE Standard ASCE/SEI 7-10; Table 20.3-1, Chapter 20, 2010.